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Solar water heating is the 'red-headed stepchild,' but metering returns it to good favor

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Abstract

The lack of meters for solar water heating technology hinders the advancement and legitimacy of the technology. Less than fifteen firms worldwide make performance meters suitable to residential solar water heating systems (SWH). The price of a residential BTU meter relative to total system cost is too expensive: sometimes more than 10%. The market is expanding for affordable meters, since the largest global growth in SWH installations is expected in the residential sector between now and 2025. To be useful, these meters must report real-time data to the Cloud and provide a user-friendly Energy Dashboard. Interviews with 26 utility executives and manufacturers in North America identified common concerns. Unmetered residential systems fail to:

i) assure long-term SWH system functionality;
ii) participate in the Renewable Energy Credit, CO_2 reduction, or pay-for-performance markets;
iii) verify that public subsidies or rebates for SWH are well-spent;
iv) use "Big Data" to innovate design or develop competitive advantage;
v) provide the information key to "bragging rights," which compel pride in ownership.

Though cheap natural gas is the primary reason the US market lags that of the world, there is no reason why distributors and installers should not professionalize their offerings with meter technology. A low cost, accurate, Cloud-tied, BTU meter increases business for installers and benefits the entire value chain.

Keywords: Metering; BTU Meter; residential solar water heating; Big Data; US market renewable market

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1. Introduction

1.1 Untapped potential for the "family renewable"

Solar water heating technology (SWH) is a cost effective solution for residential renewable generation. The average installed residential system costs between $6,000 and $10,000 — more compelling residential investment than solar PV. SWH systems can cost 1/8 the price of similarly powered, residential solar PV. [1]

Despite market enthusiasm in the 1970s — recall that Jimmy Carter installed solar hot water panels on the roof of the White House in 1979 — today US interest in SWH is sluggish. President Reagan removed Carter's SWH panels seven years after installation; most live now in the Solar Science and Technology Museum in Dezhou, China. It was the chairman of the world's largest solar hot water panel manufacturer, a Chinese company, who accepted the donation for permanent display in the museum.[2] According to the Solar Energy Industries Association, the United States composes just 1.3% of installed solar thermal market, globally. An average of 40,000 systems is installed in the US each year. [3] The North American solar thermal is valued at $500-600 million. Though valuable, solar PV is a $5 *billion* market. [4]

In Europe, the energy produced by solar thermal installations is equal to that of solar PV and wind combined. Solar thermal is seen internationally as a modernized heat system, rather than alternative technology. In China, the government set goals to install 300 million M^2 of residential scale solar hot water heat by 2020. China already composes 66% of the global market. The Chinese target for installs is 7.5 times that of the nearest competitor, India, whose goal is 40 million M^2 in the same time period. [5] Lester Brown of Earth Policy Institute writes that SWH "is sweeping China like wildfire. " Some villages have already achieved market saturation. [6]

Some think that the US market is poised to launch. Greg Katz, president of the venture capital firm, Cap-E said, "solar thermal is going through a very steep inflexion point right now," in keynote comments before the National Renewable Energy Lab's Partnership Accelerator conference. The Colorado Solar Energy Industries Association announced that retail distribution of solar thermal in Colorado increased 40% in 2009. [7]

2. Section One

2.1 Unmetered systems exert a negative force on the sector

Lack of performance metering is a major trawl on the promised momentum for which the solar water heating sector hopes. Systems have a reputation for unreliability. Without meters, SWH systems can't report failure, or impaired function. An Internet-tied meter remedies this. According to Sandia National Labs, residential system owners are "often not aware of a failure because the backup system silently continues to produce hot water. Thus, a repair event may not be generated in a timely manner, if at all." [8] The auxiliary boiler provides domestic hot water even when the SWH system fails. The homeowner perceives no difference: hot water is nonetheless hot. [9] Given the invisibility of system operations, and the presence of a back-up energy source, it is all the more serious that installers meter their systems. Meters are as essential to a system as the dashboard is to a vehicle. Without a meter, SWH systems can't be considered energy saving equipment, long term. Performance metering is foundational, if the SWH sector wants to expand and professionalize.

Without a meter, customers eventually discover their system has failed. When the repairman tells customers the system hasn't worked for months, he confronts disappointment. Customers' antipathy

toward the product sprouts. Evidence from utility research suggests that when repairs cost more than $500, customers skip the maintenance, and abandon their SWH system. “Building inspectors will tell you about lots of orphaned systems,” says Bill Spratley, the Executive Director of Green Energy Ohio, who rebates in statewide. [10]

In 1993, The Wisconsin Public Service Corporation (WPSC) launched a campaign to rehabilitate orphaned SWH systems. WPSC identified 1,119 systems possibly in need of rehab. WPSC offered $75 toward any necessary repairs, after the homeowner paid for a $50 diagnostic of the system. Forty-three percent, or 479 homeowners had either removed the system, were disinterested in the initiative, or did not return calls. Positively, the 373 systems that were serviced could be repaired for just $274. [11]

Are meters a panacea?

Yes. Especially if the meter reports remotely, through a Cloud-based interface.

Yes, if metered system data populates an Energy Dashboard the client can easily access.

Reliability, transparency, and accuracy are the missing elements of professionalism for which the sector cries out. Meters antidote these deficits.

Reliability: Email alerts and Energy Dashboards show installer and client immediately if their system is underperforming or broken. The installer is empowered to provide timely service calls.

Transparency: The solar installer can cites performance data when making repair recommendations. Meters elevate troubleshooting from an art to an educated science.

Visibility: the client’s Energy Dashboard delivers reports on expected vs. actual energy harvest. Results reassure the client, and keeps the claims made by sales force honest. Metered systems are professional systems.

2.2 Definition of key terms related to monitoring

Performance metering is not energy monitoring. Energy monitoring compels conservation based on real time feedback from electric or gas consumption. Performance metering doesn’t depend upon behavior. Rather performance metering reports system functionality, calculates payments due in a Power Purchase Agreement, and is the speedometer and odometer of a properly installed system.

The term “controls” is common parlance in energy and building management. Defined technically, and specific to the SWH industry, controls take an active role in governing system operations. Here, controls do not reference the solar controller standard to most systems. Controls are devices that advance the components to self-learn; optimize pumps; intelligently harvest and store heat; and govern the auxiliary boiler or HVAC system. What is common to “energy monitoring,” “performance metering” or “controls, “ is the implied use of smart devices to optimize functions.

When a SWH system is “metered,” thermal generation is measured. “Meter” implies fitting a solar loop’s Go and Return pipes, and peripherals, with devices to measure changes in temperature and flow over time. This data is recorded in context. Smart meters report data in real time to the Internet, or Cloud. Smart meters send an alert when a pump fails or a substandard thermal harvest occurs.

2.3 Critique of SWH meters available on the market and installers’ tepid acceptance of meters

Less than fifteen firms, internationally, manufacture a heat meter appropriate for a residential SWH installation. Some firms integrate BTU meters into the solar controller, but require additional hardware, incurring cost. Most controller/heat meters lack an engaging customer interface but rather are a diagnostic tool for installers. The average price point for today’s meters limits sales. The author’s research, in 2012, shows that the average BTU meter retails to installers for $600. The kit of plumbing parts essential to proper install, brings the cost to $1000. Thus, the average installed residential meters costs $1600+. When

a residential natural gas fuel switcher can expect to save $125 per year in saved fuel costs, and an all-electric fuel switcher can expect to save $390 per year in saved costs, an expensive meter negates the saved costs during the first several years.

The average meters on today's market have these deficits:

- Limited ability to relay real-time data to the Internet;
- Inexact accuracy range, often defined as greater than 10%;
- Mandatory static IP address, rather than dynamic common to most residential Internet connections;
    - This saves $50- $100 a month in internet service charges and saves hours of install time;
- Clumsy interface between the meter, datalogger and the router;

Johnny Weiss, Executive Director of Solar Energy International, calls today's meters "vague and confusing" for the residential owner. Weiss notes that although SWH systems display liquid or glycol temperatures on an external gauge, this is not meaningful to most owners. "Unless you are trained to interpret these numbers, and looking around your mechanical room, temperature doesn't tell you how many gallons of hot water you can expect."

Installers' attitudes toward today's meters are ambivalent. The tradesmen most likely to advocate performance metering call it supplemental. Experience from the field reveals a spectrum of attitudes: at the worst, unscrupulous installers fear that meters expose substandard work. Some don't want to be nagged for call-backs or repairs. Others lack the technology skills that web-connected meters demand. Many understand the value of meters but find the price-to-value relationship weak. Jordan DiGiorgio, a program manager for the California Solar Initiative, said that an opt-in metering option would have provided $500 toward a meter. Only one installer volunteered to do so. [12]

Patrick Altier, of Solar Trek in Ocala, Florida believes that some installers "oversell their product" and thus don't want customers to see actual (lower) BTU production or cost savings. Inarguably, cost remains an issue: "Solar Trek hasn't found a price-effective meter where it just makes sense to install them on every residential system. I calculate added-costs in terms of how many months of solar savings this meter will sacrifice" Altier said. However, on Solar Trek's metered systems, Altier is proud of the client care metering enables: excellence. "When I view all my metered systems on my Dashboard, and determine that a problem exists before the client even knows, it makes me look like the solar hero taking care of my customers," he said. [13] "Fleetview" persuades installers that meters offer their clients better service and revenue opportunities.

By contrast, most PV systems are not only metered by offer smartphone apps and extensive user interface. Every solar PV systems is metered, since metering is integral to a solar inverter. In fact, SWH is an outlier from every other form of renewable generation, wherein metering is a non-negotiable system component. According to Werner Koldehoff, Board of Directors of the German Solar Industry Association, the lack of solar hot water monitors remains a problem worldwide. "We must change the notion of solar hot water controls to be a 'must have' instead of a 'nice to have' in the eyes of the end client. Fundamentally, we must give solar thermal a new image and new credibility through measurable capacity and performance guarantees." [14]

2.4 Development of a US Heat Meter Standard

Meters certified to a national standard guarantee the market reliable equipment. In December 2011, the US Environmental Protection Agency called on the International Association of Plumbers and Mechanical Officials and ASTM International to develop a standard for energy performance metering equipment sold in the US. James Critchfield, the Director of EPA's Clean Energy Market Development,

led the group of 150 stakeholders from manufacturing companies, trade associations, Public Utility Commissions, and utilities, to request a comprehensive standard that pertains to many thermal technologies —from solar, biomass, and geoexchange, to district heat, and combined heat power. The EPA believes that a US standard "will further the development and use of thermal energies worldwide." [15] IAPMO and ASTM agreed in January 2012 to respond to the EPA request and promulgate this standard through a transparent, consensus-oriented, public process. This began in early 2012 and will take between 6 and 24 months.

State or utility run incentive programs for SWH that demand meters reference European Standard EN 1434, or the International Organization of Legal Metrology (OIML R 75) heat meter recommendation. Why isn't the SWH community satisfied with this existing criterion? Practical obstacles to widespread adoption of EN1434 or OIML are real.

- Lack of US laboratories authorized to test to EN1434. The EU and US deploy different communications protocols (i.e. Modbus vs. M-bus).
- Technical inconsistencies exist in terms of the metrics used to measure the execution of various functions
- When a state program specifies a meter, and no national guideline exists, states may promulgate independently.

Standards address methodology and not technology. A standard lays out the expected minimum terms for metering instruments: the technical approach to calculate ΔT, the stated accuracy of readings, data storage, interface with the Cloud, and communication protocols for instance.

Multiple state standards would add cost for manufacturers and hurt the manufacturers. The California Public Utility responded to the lack of a national meter standard by encouraging the Solar Rating and Certification Corporation(SRCC) to modify EN 1434 to the US market. This process preludes the ASTM dialogue; it illustrates the urgent need for a national standard, to which ASTM is now responding.

3. Section Two

Unmetered residential systems restrain the sector's professional reputation and market growth. Without meters, the sector cannot:

i) assure that the SWH systems remain functional;
ii) participate in the Renewable Energy Credit (REC), CO2, or pay-for-performance markets;
iii) verify that public subsidies or rebates for SWH are well-spent;
iv) use "Big Data" to innovate upon engineering or develop competitive advantage;
v) provide the "bragging rights" which compel pride in ownership.

3.1 Without metering, it's not easy to prove the system is working

Public confidence in SWH technology is low for good reason: system failure has historically been pervasive. A 2009 Sandia National Labs report synthesized data on systems installed between 1970 and 1990. Fifty percent failed within ten years of installation. Valves, pumps, collectors, and sensors are among the leading cause of failure. [16] A smart meter would have identified each of these broken components quickly and hastened repair. Like all mechanical systems that involve heat, pumps and water, failure is not unusual. What is unusual is that SWH can fail silently and remain broken for years, unnoticed. The crucial timeframe to be vigilant about system breakdown occurs five years after installation and on. For instance, no pump on the market has a warranty greater than 5 years.

Any meter is better than no meter. But a meter that reports to the Cloud has quickly become a best practice. The meter-to-Cloud interface most firms offer needs additional hardware. Most are cumbersome

to install. Dataloggers can add hundreds of dollars to a meter package. The California Center for Sustainable Energy's Solar Water Heating Program Final Report (from San Diego's 2007 pilot) metered 100 systems for performance. The results were seriously compromised by gaps in data collection thanks to clumsy network engineering, and inconsistent data report intervals. [17] To remedy this, high-speed Internet is a must, so that bandwidth is not a constraint. Data must be stored on the device so that when the Internet can't be reached, no performance information is lost. Engineering can limit the costs of additional hardware. Meter-to-Cloud reporting empowers customers and installers alike, and streamlines performance validation for pilot projects.

3.2 Participate in the growing Renewable Energy Credit (REC) market, CO2 or Pay for Performance Markets;

Solar water heating systems can't participate in the active and growing Renewable Energy Credits (REC) market since energy production can't be stated. RECs, or (aka Renewable Energy Certificates) are traded to help utilities comply with the mandatory targets set by States for renewable fuel supply. Forty-two US states have a Renewable Portfolio Standard (RPS). But not all utilities can install sufficient generation in a timely or cost effective way. So, utilities buy credits representing renewable energy generated elsewhere and book the generation toward their required generation. A REC is widely fungible, not tied to transmission, nor a geographic region. The value of one REC is equal to one megawatt-hour of renewable generation. The REC is a subsidiary product, of value, that is separate and in addition to the actual commodity of electricity.

RECs primarily encourage renewable electricity generation, but thermal RECS also exist. To sell a qualified REC, the developer must prove that the specified amount of energy was generated. While residential PV owners have enjoyed the dividends of REC sales, no such payment accrues to unmetered solar thermal systems. Though residential thermal RECs are tiny, when bundled and sold by a third party they are valuable.

Lakeland Electric in Florida was first in the nation to sell solar thermal RECs. The Lakeland case gestures at the potential for thermal REC sales earned from the residential market. Chip Bircher, chair of the Utility Solar Water Heating Initiative (USH2O), called the Lakeland REC transactions "landmark for the solar hot water industry." [18] This was possible only because they demanded meters on residential and commercial projects. Jeff Curry, program director, said, "In the future we will sell our RECs. We are betting on the fact that we'll need them." [19] REC prices aren't lucrative, but they are material. As of December 2010, RECS for solar thermal projects in Washington, DC and North Carolina sold for $290 per thermal MW.

Carbon offsets are another potential byproduct of value. An average residential system can offset between 3,000 and 5,800 lbs of CO2 per year, depending on the replaced auxiliary fuel.

Performance payments are a popular method to structure incentives (rather than rebates). In order to use the performance payment method, a meter must be installed on the system and capable of uploading daily performance data to the rebater. The incentive paid is based on the KWth generated (a thermal measurement).

3.3 Meters verify that SWH incentives are effectively spent

Interviews with 26 utility companies and rebating organizations found that a BTU meter is rarely mandated residential systems. Commercial installs and pools are usually metered. Yet, validating system performance in year one is not sufficient; checking system operations in years 5-20 is relevant: this is when systems fail and the meter proves its worth.

Utility or municipal incentive programs drive the US market for SWH. Chip Bircher, chair of USH2O, observes that SWH has taken off only in states that count thermal technologies toward their Renewable Portfolio Standard (RPS). Utility companies are motivated to rebate SWH systems as a demand side management tool. Lakeland Electric's program director Jeff Curry says that switching to SWH reduces the average residential energy requirement for heating water by 70%.

Surprisingly, every program nationwide is reluctant to encourage residential meters. Regulated utilities, city councils, or boards of directors need proof that SWH rebates are used wisely. The sentiment is strong that mandatory meters saddle homeowners with additional costs. Most organizations admitted that monitoring "was a good idea," or "something we should consider." Large-scale incentive programs like the California Solar Initiative (budget of $180M) and the Mass CEC's Commonwealth Solar Hot Water (budget of $10M) mandate or pay for residential meters. The meter is too expensive for modest incentive programs. "At $450 per meter, I just laugh," said Kevin Howerton of Greys Harbor Public Utility District. "The cost [per meter] is too great a percent of my entire program budget." [20]

The Lakeland model is to provide customers solar hot water for a flat monthly fee of $34.95, wherein a third party owns and maintains the systems. Since 1996, one hundred percent of the SWH systems Lakeland installs has a metering/monitoring device, provided at approximately $400 per system by Metrima, a Swedish firm. Curry believes meters uphold the principles on which utility service is grounded. "For 100 years the utility industry has insisted that you can't sell unmetered energy. We have to stand behind metering as the backbone of retail energy delivery. The meter proves that we deliver something of value. This stands above system operations or performance verification or REC sales. Meters are a utility ethic. Meters are in the utility company's best interest." [21]

Residential thermal systems are not metered. Rather, the expected performance is derived from the SRCC's OG-300 standard. So, two full time inspectors commission systems to attest that they comply with the Solar Rating and Certification Corporation's OG-300 Standard. Program engineer Joel Dickinson feels that his program is hampered by what the market offers at this time. Dickinson tested various BTU meters to roughly validate their performance. Three meters monitoring the same solar loop over a six-month period demonstrated greater variability than the stated accuracy range of 2 to 5%. For Dickinson, metering the systems provides the benefits of assurance that incentive funds are well spent. He hopes that a cost-effective and accurate meter will come to market. [22]

The Massachusetts Clean Energy Center's solar water heating initiative provided $1000 toward the cost of a residential meter. Initially, about half of the residential installations were equipped with meters. "Once installers were familiar with the program, many more signed their customers up right away," said Christy Howe, Project Manager at the Mass CEC initiative. Christopher Beebe, Principal at BEAM Engineering who consults with Mass CEC on this project notes that, "there is a certain liability for the installing contractor on metered projects, so we hope this encourages better performing systems over the long term." Howe added that "some meters have been inconsistently installed," and reiterated the value education brings to any metering launch. Beebe drew the comparison that "in the ESCO world there are clear expectations for how energy savings should be measured and verified," and noted that in the SWH sector, "metering has been severely lacking." [23]

Green Energy Ohio (GEO) offers an average of $2,400 per system in rebates. The program doesn't meter any rebated projects, though GEO's Executive Director, Bill Spratley said repeatedly that such technology, if affordable, would be useful. [24]

The California Solar Water Heating Pilot Program ran between 2007 and 2010 in the San Diego area. In the final evaluation report, it concluded that, "Accurate and reliable metering is critical to evaluating ongoing system performance, providing host customer feedback, and enabling potential leasing arrangements and renewable or GHG credits." [25] Program Manager, Jordan DiGiorgio, worked on the

2007 pilot and is involved with its successor initiative. “We are seeking guidance from the California PUC on the form and nature of the statewide metering plan,” she commented.

Performance metering is a priority among the foremost utility, or State-sponsored campaigns. Budget constraints were the most prevalent constraint.

3.4 “Big Data” from thousands of systems empower innovation and better service

Data that SWH meters gather appears boring. In fact, what appears to be “exhaust data” is rich with potential. Solar yield measurements, time-stamps, site orientation, climate zone, demographics, DHW water consumption, and manufacturers’ comparative performance are but the green shoots that indicate the breadth of information possible to gather and usefully assess.

An emerging term for this aggregated volume of information is “Big Data.” Big Data references the information that is “beyond the ability of traditional database software tools to capture, store, manage, and analyze.” [26] McKinsey Global Institute reports that Big Data will become a major market driver in coming years. It’s forecast to enable a 60% increase in retailers’ operating margins, save $148B in operational efficiencies within the global government sector and add more than $300B in value to the market annually, according to 451 Research Group. [27] Big Data collection hinges on sensors. Today, 30 million sensor nodes are in place in the transportation, auto, retail, industrial processing and utilities sectors. Disney, Orbitz, CenturyLink, Groupon and 3,700 other companies internationally are actively developing a Big Data strategy.

Big Data analysis on SWH meters opens the door to improved manufacture, and tailored owner interface.

- Imagine if system failures nationwide were tracked. When energy harvest, and component failure data is queried to look for potential design innovations, then engineering and manufacturing improve.
- Imagine if system data was linked to installation site. When the influence of climate, temperature swings, shading, and panel type is queried, installers could substantiate system recommendations with proven performance. Best-fit technologies particular to a region could be indicated.
- Imagine if exact DHW consumption patterns were tied to demographics like family size, age, or income class. Big Data analysis could explain why lower income residents use more hot water than the national ASHRAE standard.

Employing Big Data analysis is not entirely new to the renewable sector: Vestas collects performance and weather data on every turbine ever installed.

Smarter data will yield smarter devices, and smarter devices yield smarter data. “There is no such thing as stale data. There is no such thing as uninteresting data. The fact that is uninteresting makes it interesting to me,” said Michael Lopp, Director of Palantir Technologies, which queries Big Data sets. [28] McKinsey fellow Michael Chui said of Big Data, “Big Data will be a key basis of competition … and can truly enhance the productivity of economies.” Big Data pushes astonishing market innovation. Controls and meters are the intelligent components essential to reach this frontier.

3.5 Metering gives system owners the “bragging rights” that build pride in ownership

It often takes months or years before system owners realize their SWH system doesn’t work. Then systems are commonly orphaned because owners have lost interest in repair or maintenance. When meters relay data to an energy dashboard, the system owner has a tangible, daily report from the system. Patrick Altier of Solar Trek notes the median age for a SWH install customer is 52. The mature audience is

ostensibly not techie. Nonetheless, Altier has found them to be deeply engaged and proud of the energy dashboard which he offers with each system. “My clients can look at their dashboard from their easy chair and see system performance. I provide them a freestanding console. They show the dashboard to their friends. They are psyched!”

Energy dashboards turn invisible hardware into a tangible asset one can interact with from the living room. Bragging rights and the status that high-tech dashboards convey motivate purchase decisions. As the uptake of home energy monitoring devices drop in price and increases in adoption, the public is coming to expect smartphone apps and elegant data delivery.

Jerry Marizza, the New Energy Program Coordinator at United Power in Colorado says, “If you let the utility bill tell the whole story, the customer has no visual. The industry needs to put some sizzle on SWH! Customers want the visual!” [29] Monitors build a rapport between homeowners and their investment, which then encourages maintenance and repair. “Metering and energy metrics -- this is the sexy factor we need to bring to solar water heating,” said Matt Carlson, CEO of Sunnovations, a SWH technology innovator in the residential sector. [30]

It is intuitive that infrastructure like SWH which appears redundant will be overlooked and discounted. Recognizing this, the SWH sector should consider features that help owners remain engaged. Although the link between monitoring and reduced electricity consumption is substantiated by more than 30 international studies the potential for monitoring to build a relationship to motivate system repair or maintenance awaits further assessment.

4. Conclusions

Though solar water heating remains a niche market for Americans, it is a dominant technology in the rest of the world. Given that Americans spend $32 billion on DHW annually, composing between 50 and 80% of residential utility bills, the potential for smart SWH systems is tremendous. [31]

Still, SWH systems are seen as the “redheaded stepchild” of the renewable sector. To overcome this outdated reputation, meters professionalize SWH’s image by offering reliability, transparency and accuracy. All residential systems need a cloud-tied BTU meter. All residential systems would benefit from an Energy Dashboard populated with metered data. Metered systems 1) prove ongoing functionality; 2) allow thermal producers of all scales to participate in the REC market; 3) verify that rebate funds were judiciously spent by utilities or public entities; 4) use Big Data for a profit; 5) enable SWH owners to take pride in their systems and consequently, maintain them.

Experts note that some customers see SWH as an “old technology,” and are counseled to “get rid of their SWH system to make room for solar PV.” Cost effective, Cloud-tied, real time metering with consumer-friendly energy dashboards will help the sector the sector prove its worth and build its case.

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